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AN OPTIMIZATION OF HIGH PRESSURE AND TEMPERATURE OF SYNGAS IN UNDERGROUND COAL MINES BY USING CFD ANALYSIS OF MEMBRANE SERPENTINE TUBE

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ABSTRACT

The membrane serpentine tube heat exchanger is very useful for various applications such as aerospace, automobile, gas turbine power plants, chemical reactors and other industries, etc. This research deals with the thermal analysis of heat transfer for flowing fluid through tubes using ANSYS FLUENT R18.0. This membrane serpentine tube heat exchanger arrangement can provide aids a large transfer heat area in a small space with coefficients of heat transfer is high. For the construction of membrane serpentine tube heat exchanger, copper is choosing. Syngas is flowing through the conduit and also at the outer shell of the winding tube heat exchanger. In this precise research, an effort is made to evaluate the effect of Optimization of High Pressure and Temperature of Syngas in Underground Coal mines from a membrane serpentine tube heat exchanger, where the cold fluid flows on the tube and the Syngas flowing in the cell of the membrane serpentine tube heat exchanger.

KEYWORDS: Membrane Serpentine Tube Heat Exchanger, Syngas, Underground Coal Mines & CFD

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Original Article

1. INTRODUCTION

Concerning about construction type, heat exchangers can be arranged on regenerative, tubular, plate-type and heat exchangers with elongated surfaces. Heat exchangers with elongated surfaces are composed of elements that are correlated to a primitive facade that is in direct contact with both hot and cold fluid. These elements are referred to as fins. The primary use of extended surfaces is to increase the heat transfer area. Compact heat exchangers are widely used in many ways in residential, commercial and industrial HVAC systems. Fin-and-tube heat exchangers are representatives of compact heat exchangers with high compactness ratio. In this paper, CFD analysis of membrane serpentine tube heat exchanger has been performed.

The global concerns are that the syngas will rise in the underground mines. Membrane Serpentine Tube Heat Exchanger is a vital Heat Exchanger to reduce the high temperature and high pressure of syngas in underground tunnels. This CFD analysis has been done as preparation for testing of heat exchangers with microchannel coil. CFD analysis procedure with syngas and waterside model has been used. Syngas and water model allows the implementation of some scaling effects (entrance effects, conjugate heat transfer and viscous heating).

1.1 Applications

Use of Membrane Serpentine Tube Heat Exchanger for heat transfer utilisation

- The serpentine membrane tube is eminently suited for studying the characteristics of a plug flow reactor in reaction kinetic studies.
- Membrane Serpentine Tube is used for transferring heat in chemical reactors and agitated vessels.
- Because of the compact configuration of membrane serpentine tube heat exchanger, they can be readily used in heat transfer application with space limitations, for example, in steam generations in marine and industrial applications.

2. CFD ANALYSIS OF MEMBRANE SERPENTINE TUBE HEAT EXCHANGER

(CFD) Computational fluid dynamics investigation begins with the development of required geometry supported by mesh generation. Meshing is the discretisation of the area into small volumes where the governing equations determined with the help of iterative techniques.

Besides, modelling proceeds with an allotment of boundary and initial conditions for the area and leads to modelling of the entire system. At the end of this iterative explication steps, we can take the statistical and graphical output of the analysis.

2.1. Delineation of the Geometry

The gas flow module from the workbench is chosen. It is a standard type of heat exchangers used in heat transfer applications; the membrane serpentine tube heat exchangers are still the most common type in use. Membrane, Serpentine Tube Heat Exchanger geometry, is constructed in the ANSYS R18.0 Naming of various parts may be done in this step by design modeller.

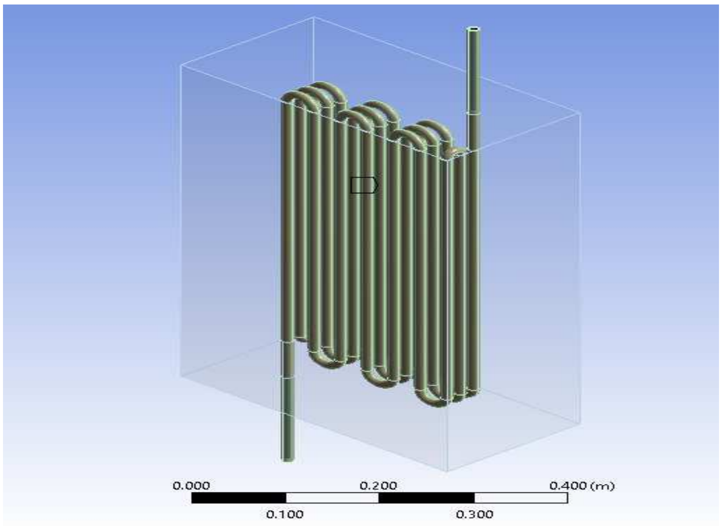

Figure 1: Geometry of Membrane Serpentine Tube Heat Exchanger

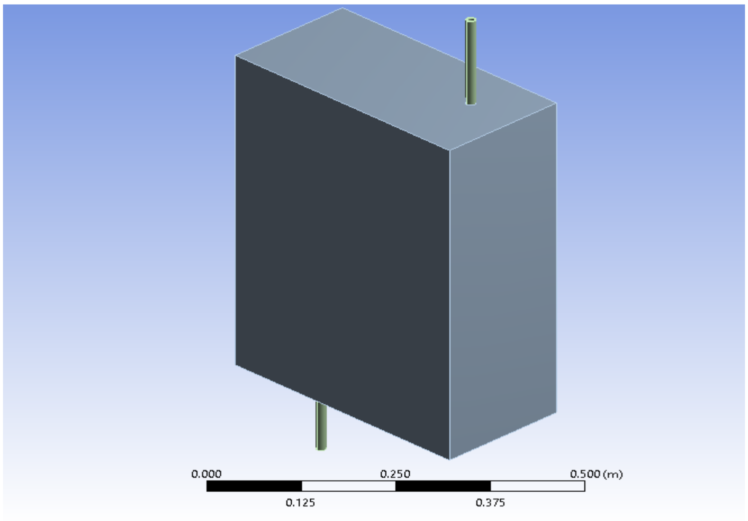

Figure 2: Geometry of Membrane Serpentine Tube Heat Exchanger

Figure 1 and Figure 2 shows the geometries of the serpentine tube heat exchangers with three types of membrane arrangements called configuration 1, configuration 2 and configuration 3, respectively. The geometrical parameters for membrane helical coil heat exchanger are given in Table 01.

Table 1: Geometry Parameter

Sr. No.	Parameter	Dimension
1	Length of heat exchanger tube	0.5m
2	Diameter of tube (d)	10mm
3	Radial pitch between serpentine tube (p_1)	20 mm
4	Thickness of tube (t)	2mm
5	Inner Diameter of tube	8 mm

2.2. Meshing

The 3D mesh system was established using the commercial code GAMBIT based on the 3D geometry. At first, a relatively coarser mesh generated. The mesh contains tetra cells and hexahedral cells (i.e., mixed cells) having both triangular and quadrilateral faces at the boundaries. The meshes of the computational model for configuration1 are shown in Figure 03 and Figure 04.

It is meant to reduce the numerical diffusion as much as possible by suitably structuring the mesh, particularly near the wall region. In meshing stage, named selections specified like cold inlet, cold outlet, hot inlet, hot outlet etc. The commercial code ANSYS R18.0 is adopted to simulate the flow and heat transfer in the computational model.

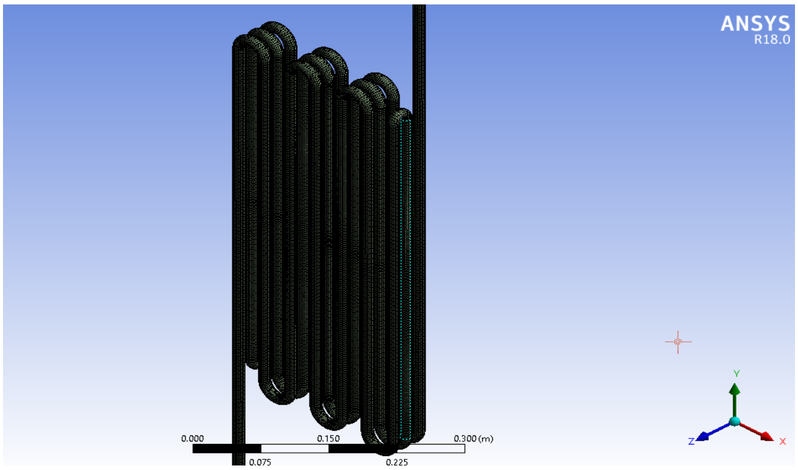

Figure 3: Meshing of Membrane Serpentine Tube Heat Exchanger

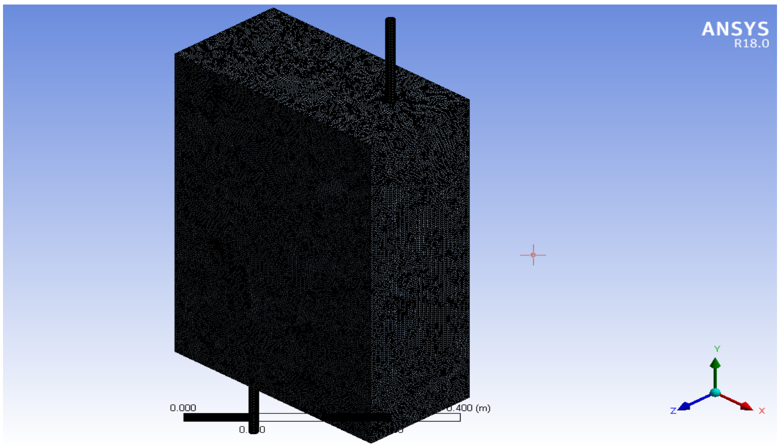

Figure 4: Meshing of Membrane Serpentine Tube Heat Exchanger

2.3. Setup (Fluent)

The mesh is checked, and quality ensured. The analysis type altered to Pressure Based type. The velocity formulation assigned as ‘absolute’ and time to ‘steady state’. Energy option set to ON. The viscous model selected as “k-ε model”. The edit option is clicked to add water-liquid, nitrogen-gas, copper tube material, to the list of gas and fluid respectively from the fluent database.

In each analysis, different geometry parts of the heat exchanger assigned as corresponding fluid (e.g., water) and gas (e.g., syngas.) as per the criteria.

Boundary conditions assigned according to the need of the model. The inlet conditions defined as ‘mass flow inlet’, and outlet conditions set as ‘outflow’. Two inlets and two outlets determined by considering hot gas side and cold fluid side. Each wall separately specified with respective boundary conditions. Each partition set to no-slip condition.

The Details of Boundary Conditions are as Follows

- **Gas:** Syngas and Water
- K-epsilon, realizable model, Scalable wall function
- Turbulence intensity- 5% & ratio- 10

- **Water Inlet**

  Pressure- 1 bar

  Temperature-38^{o}**C**

- **Water Outlet**

  Mass flow rate-0.167kg/s

- **Gas Inlet**

  Pressure- 245166Pa

  Temperature- 55.2^{o}**C**

- **Gas Outlet**

  Mass flow rate-0.167kg/s

- **Tube:**

  Convection-500w/m2k

  Material-Copper

2.4. ANSYS Result

We have considered in this membrane serpentine tube heat exchanger analysis Copper is assigned as tube material and the

ANSYS result of Membrane Serpentine Tube Heat Exchanger for

- Temperature of Gas Domain,
- Temperature of Water Domain and
- Pressure of Gas Domain are obtained are as follows

2.4.1 Temperature of SYGAS Domain

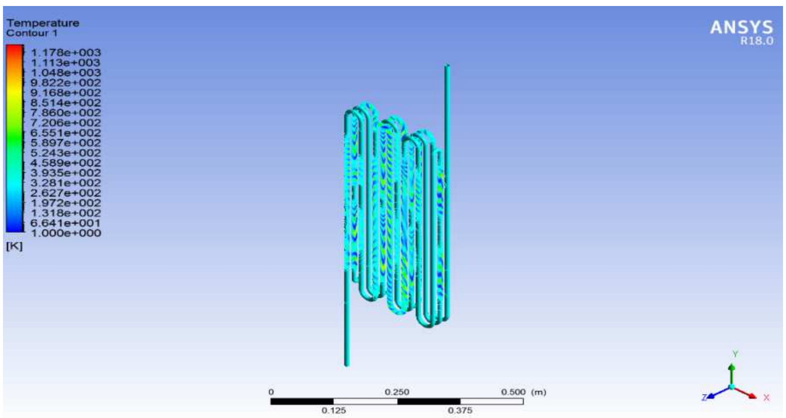

Figure 5: ANSYS Result of Membrane Serpentine Tube Heat Exchanger (Temperature of Syngas)

2.4.2 Temperature of Water Domain

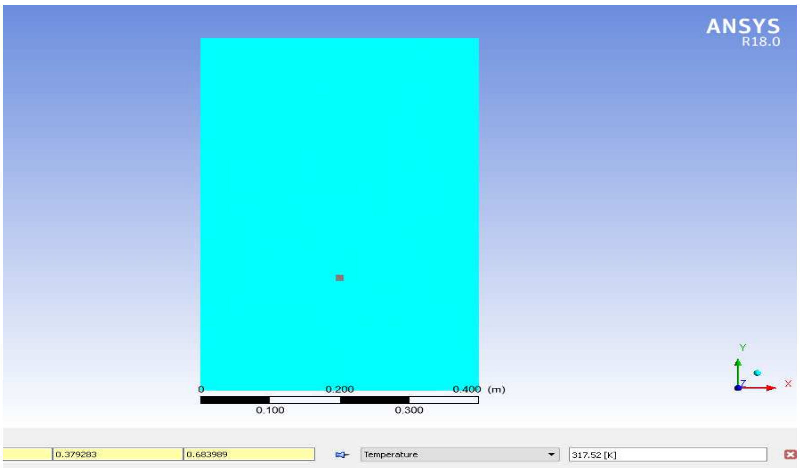

Figure 6: ANSYS Result of Membrane Serpentine Tube Heat Exchanger (Temperature of Water)

2.4.3 Pressure of SYNGAS Domain

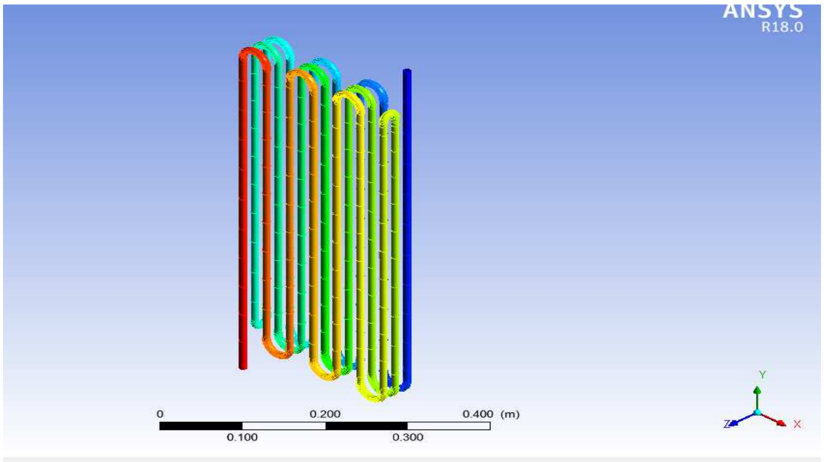

Figure 7: ANSYS Result of Membrane Serpentine Tube Heat Exchanger (Pressure of Syngas)

Table 2: Temperature of Gas and Water Domain

Type	Mass Flow Rate (kg/s)	Inlet Temperature (K)	Outlet Temperature (K)
Gas	0.167	328.2	311.1
Water	0.167	311	317.52

Table 3: Pressure of Gas Domain

Type	Mass Flow Rate (kg/s)	Inlet Pressure (Pa)	Outlet Pressure (Pa)
Gas	0.167	237569	1327

3. CONCLUSIONS

Optimisation of High Pressure and Temperature of Syngas in Underground Coal Mines by using CFD Analysis of Membrane Serpentine Tube performed under various operating temperature, pressures, and inlet velocities. The significant

findings summarised as follows:

- Heat transfer analysis of a Membrane Serpentine Tube Heat Exchanger using CFD code ANSYS R18.0 has been present in this paper.
- Three-dimensional numerical simulations for Serpentine Tube Heat Exchanger with different membrane configuration and working condition are performed to reveal the effects of membrane configuration and working condition on the heat transfer and pressure drop characteristics.
- Higher operating pressure and temperature of syngas from underground coal mines, however, brings more significant pressure drop because of the Membrane Serpentine Tube Heat Exchanger.
- The syngas flow in membrane serpentine tube heat exchanger is significant to heat transfer enhancement.
- The syngas velocity in the membrane serpentine-tube heat exchanger is independent of the axial direction and approaches zero.
- Operation pressure does not exert any influence on the velocity field in heat exchangers; however, high pressure can improve heat transfer through the increase of the syngas mass flow rate.

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